NEWER VOLCANIC VENTS AND LAVA FIELDS BETWEEN WALLAN AND YUROKE, VICTORIA

By Walter Hanks

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Introduction

The Newer Volcanic vents between Wallan and Yuroke are located in the Shire of Broadmeadows with the exception of Hayes Hill which is in the Shire of Whittlesea. They form part of a linear series which extends from Kilmore to one mile south of Yuroke and their lava fields are considered to be the eastern end of the basaltic plain of Western Victoria. They occur at intervals of 1½ to 3 miles forming a rough arc with a chord of 25 miles, the distance from chord to the middle of the arc (Mount Fraser) being 4 miles. The points of the arc lie about 5° west of south.

Pretty Sally Hill, 1,739 ft. (Big Hill) on the crest of the Dividing Range occurs immediately to the north where it overlies Silurian bedrock at 1,600 ft. above sea level. Pretty Sally Hill is probably a much older vent than those described since it is very decomposed and caps ridges separating valleys cut in Silurian sandstones which have been later filled by flows from vents to the south of it.

The only literature on the volcanic rocks of this district is contained in the Geological Quarter Sheets surveyed in 1856-1857 and a reference by T. S. Hart[1] which states that the old valley down which the lavas flowed was probably divided into two, mentioning Hayes Hill as the source of the lava which extends south as far as Melbourne. Hart also describes Mount Fraser and Aitkens Hill.

The map (Fig. 1) and contours are copied from the Military Map of the district. The boundaries of the lava fields of the various points of eruption are shown, the order of their age, so far as could be determined, being indicated by the number designating them, No. 1 being the oldest. The investigation revealed some unrecorded inliers of sedimentary bedrock of presumed Silurian age and granodiorite which have been mapped.

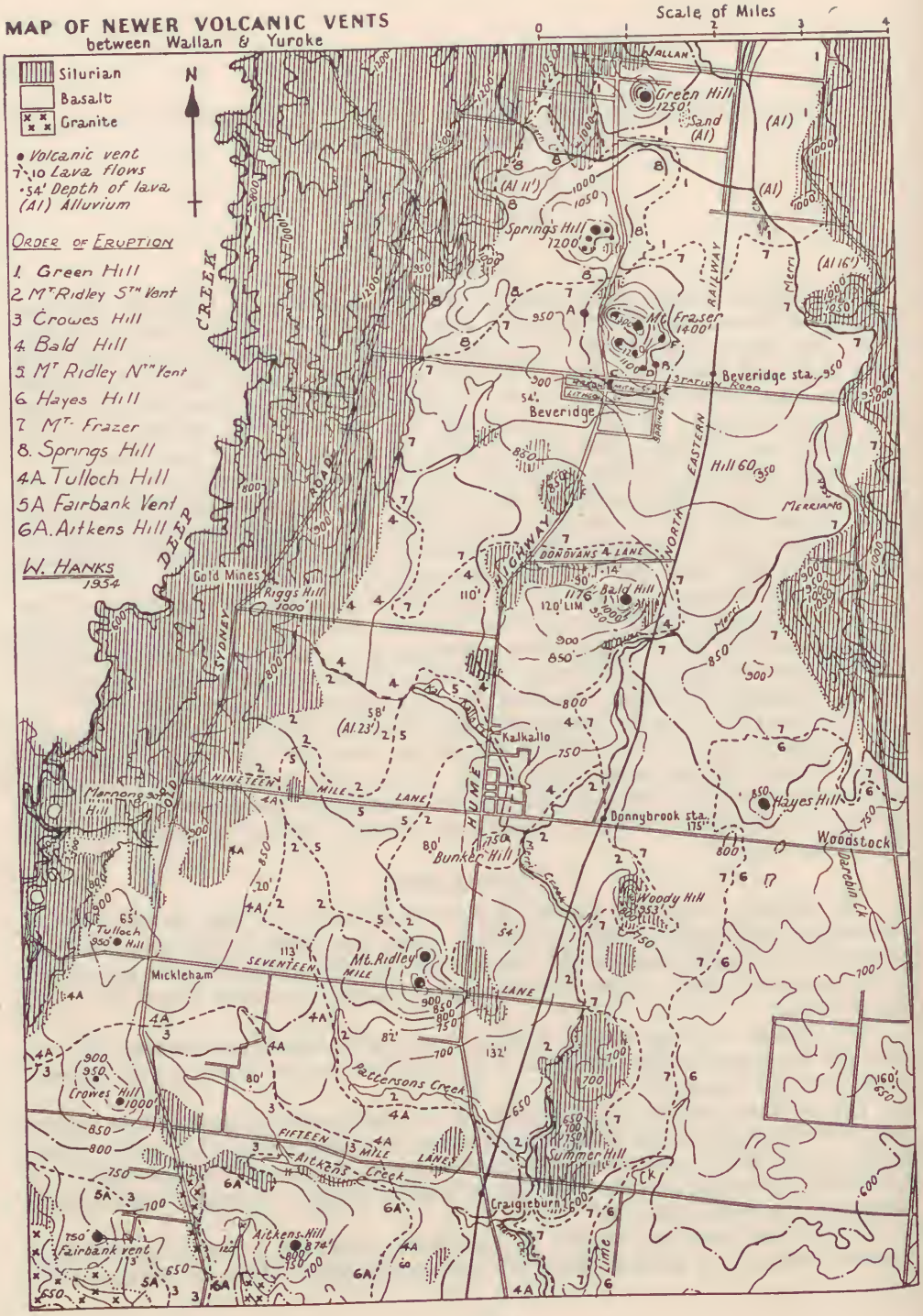
Physiography

The volcanic vents have erupted at different times over a long period and bear no relation to the present hills and valleys. Lavas from them issued over a terrain of low hills and valleys composed of sandstones and siltstones of Silurian age except in the south-west corner of the area where granodiorite of probable Upper Devonian age outcrops.

The present drainage system is immature, much of the water sinking into the lava and flowing as ground water. It is the result of repeated changes, consequent upon the volcanic activity.

The northern part of the area prior to the lava flows consisted of two valleys and their interfluves on the southern side of the Dividing Range. The gradient from Wallan to the 600 ft. contour on the western interfluve is about 43 ft. per mile over a distance of 14 miles and there is a steady gradient from the Silurian to the granodiorite on its south-west end.

Four of the vents are located on the middle interfluve which is obscured by volcanic debris. It is 1,100 ft. above sea level at Wallan, 1,150 ft. at Springs Hill,


MAP OF NEWER VOLCANIC VENTS
between Wallan & Yuroke
Scale of Miles
0 1 2 3 4
Silurian
Basalt
Granite
N
• Volcanic vent
7 10 Lava flows
•54' Depth of lava
(Al) Alluvium
ORDER OF ERUPTION
1. Green Hill
2. Mt Ridley 5th Vent
3. Crowes Hill
4. Bald Hill
5. Mt Ridley Nth Vent
6. Hayes Hill
7. Mt. Frazer
8. Springs Hill
4A. Tulloch Hill
5A. Fairbank Vent
6A. Aitkens Hill
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1954
Wallan
Green Hill 1250'
Sand (Al)
Springs Hill 1200'
Mt Fraser 1400'
Beveridge sta.
Beveridge
Hill 60
Merriang
Donovans Lane
Bald Hill 1176
Gold Mines
Riggs Hill 1000'
Kalkallo
Donnybrook sta.
Hayes Hill
Woodstock
Bunker Hill
Woody Hill
Tulloch Hill 950'
Mt. Ridley
Mickleham
Patersons Creek
Crowes Hill 1000
Summer Hill
Aitkens Creek
Craigieburn
Aitkens Hill 874'
Fairbank vent
Deep Creek
Sydney Gold Road
Nineteen Mile Lane
Seventeen Mile Lane
Fifteen Mile Lane
Eastern Highway
Barrow Ck
Merri
Lime

FIG. 1

1,000 ft. at Mount Frazer, 900 ft. south of Beveridge, 950 ft. at Bald Hill, 953 ft. at Woody Hill, 700 ft. south of it and 787 ft. at Summer Hill, a gradient of 30¼ ft. per mile in 12 miles. There is a sharp drop from Mount Ridley and Summer Hill to the 600 ft. contour.

The eastern interfluve is higher, being 1,337 ft. above sea level at Cleeves' Hill and 900 ft. three-quarters of a mile north of Woodstock where it drops sharply to the Mernda Gap.

The eastern valley was wider and deeper than the western valley and was eroded by three streams that still flow into it. The Green Hill composite volcano has diverted one stream that formerly flowed south. It has been possible to find the pre-volcanic gradient from bores. The lava at Wallan is about 50 ft. deep on the 1,000 ft. surface contour and a bore at Woolert on the 650 ft. contour shows 160 ft. of basalt. The distance between these two points is 11½ miles, giving a gradient of approximately 42 ft. to the mile. The valley narrows to 1½ miles opposite Bald Hill, and the deepest part continues through Woolert and Epping.

The western valley was much shallower and narrower. It was eroded by two streams that flowed south and emerged on to the plain through a gap three-quarters of a mile wide between the present positions of Mount Ridley and Summer Hill. Below the confluence the stream continued south on a course west of the present Merri Creek. The valley seems to have been fairly wide north of Bald Hill but there contracted to 1½ miles, again widening until it reached a point one mile north of Nineteen Mile Lane. From here its western interfluve turns south-east to Mount Ridley.

The south vent of Mount Ridley, on an eastern extension of the western interfluve, erupted and filled the gap and the lower portion of the valley, forcing the stream to cut a new passage farther east between Summer Hill and a hill south of Woody Hill into the ancient eastern valley. The next alteration to the drainage was caused by the eruption of Bald Hill on the north-east side of the middle interfluve, which here is two miles wide. It discharged lava into both eastern and western valleys, the eastern receiving a large quantity of vesicular basalt, visible only near Bald Hill but probably represented in the bed of Lime Creek, and the western a large amount of lava which spread west and south. This lava in the western valley met that from Mount Ridley, causing the stream to shift to the west and find its way between the two flows. The north vent of Mount Ridley next erupted, spreading a number of small flows about the flanks of Mount Ridley and causing a small waterfall on Kal Kallo Creek.

The next change was caused by the eruption of Hayes Hill, which is almost in the middle of the mouth of the eastern valley. Its lava covered the country to the south and east. The thickness of volcanic rocks was by this time 175 ft. just south of Hayes Hill and the big valley at Woolert had been obliterated, forcing the drainage to cut a new course on the east side of the ridge of bedrock between Bald Hill and Woody Hill, where it joined the stream flowing through the gap between Mount Ridley and Summer Hill.

Mount Frazer, on the eastern side of the middle interfluve, was the next to erupt and poured most of its lava into the eastern valley, covering part of Green Hill lava and pushing tongues towards the north. It filled the valley from wall to wall down to Hayes Hill, the lava near the vents being over 200 ft. thick. It passed Hayes Hill, filling the fairly wide and deep valley which had by this time been eroded on the west of this hill. It also filled the gap north of Summer Hill between the east and west valleys and a small valley on the east side of Hayes Hill that drained to the south-east. The filling of the eastern valley caused lava to pour over gaps between

Mount Frazer and Bald Hill in to the western valley. This lava reached Kal Kallo, filling the channels being recut, but did not cover the Bald Hill lava.

At this stage the eastern valley had nearly reached its present physiography, that is a lava-filled valley with a low-lying alluvial head, swampy in winter, from which a youthful stream, the present Merri Creek, has eroded a course on the east side of the main valley across the foot of a basalt-filled valley that lies between two ridges of bedrock. The uncovered basalt commences about midway between Wallan East and Beveridge railway station, and Merri Creek has cut a gorge about 20 ft. deep on the end of the southern ridge. The gorge is in basalt except for about 100 ft. on one bend, where it flows between bedrock and basalt. The stream continues east in basalt then turns south over an alluvial flat that is probably underlain by bedrock to Beveridge Road, where it again crosses an alluvial flat 16 ft. deep overlying basalt, until it reaches a ridge of bedrock south of Merriang. It has been deflected by lava from Mount Frazer, which banked against Hayes Hill lava, and continues on a south-westerly course across the main valley, its valley being 12 to 15 ft. deep. Reaching the south-east end of Bald Hill it flows through the Mount Frazer lava into the western valley and then south between this lava and that of Bald Hill to a point about 1½ miles from its confluence with Kal Kallo Creek. The last 1½ miles is in a south-westerly direction through an alluvial flat.

Darebin Creek developed on the east side of the eastern valley, rising in Silurian bedrock north of Woodstock and making its way southward as a mere gutter on basalt.

The western valley was brought to its present shape by the eruption of Springs Hill which is astride the middle interfluve. The eruption was not of great extent but there was sufficient lava to form a barrier 50 ft. high near the head of the valley which became swampy and filled with twelve feet of alluvium. The drainage of the main streams was diverted across the interfluve into the eastern valley. The western valley was already flat from 1½ miles south of Beveridge to Kal Kallo. At Kal Kallo there is a rise to Mount Ridley from where the gradient on the south side falls from 800 to 600 ft. above sea level in 2½ miles. The low-lying parts of the valley became one huge swamp with a depth of 25 ft. of alluvium on its western side, there being only one small tributary draining into what eventually becomes Kal Kallo Creek. This joins Merri Creek which cuts a gorge first through basalt, then between bedrock and basalt at Summer Hill, and finally in basalt before it flows on to the plain.

A feature of the western valley are large alluvial fans at the foot of the hills. A deep gully south of Marnong Hill on the old Sydney Road might in time have captured the drainage for the Maribyrnong River as the gradient of the valley to Merri Creek is almost nil and the swamps mentioned are drained by large ditches.

South from about Nineteen Mile Lane the western interfluve which to the north is Silurian bedrock widens and the bedrock is interspersed with lava. Its southern and eastern limits are defined by the 600 ft. contour. The western limits are outside the area concerned but are similarly defined.

At the southern end the present drainage is by the deep V-shaped valleys, between basalt and granodiorite, of the east and west branches of Moonee Ponds Creek, which drain southward. Before the lava flows this part of the area had been dissected by deep valleys which have since been filled with lava from Crowes Hill, Tulloch Hill, Aitken's Hill and Fairbank vent. The eastern vent of Crowes Hill was the oldest and filled valleys to the west and south by way of a valley in the Silurian bedrock on its western side, also filling one in granodiorite south of it and pouring lava flows to the east. The much younger western vent filled valleys to its west. Tulloch Hill, 1¾ miles north of Crowes Hill, is half a mile east of the valley

of the Deep Creek or Maribyrnong River and evidence of the amount of erosion which occurred between volcanic episodes and to the present day is afforded in this part of the area. The valley is over half a mile wide, the bottom being 500 ft. above sea level, the precipitous eastern edge 850 ft., and the western side, which is capped by lava older than that on the eastern side, 800 ft. above sea level. It was originally eroded on the margin of Silurian bedrock and the western basalts and a tributary about $1\frac{3}{4}$ miles long with a westerly course drained into it from the south side of Marnong Hill. Measured on the western side Deep Creek valley had reached a depth of 125 ft. when lava from Tulloch Hill flower down the tributary into it for a short distance, filling both valleys to a depth of about 30 ft. with basalt, which has since been reduced to about 25 ft. by erosion. Deep Creek has since cut a new valley between the western side and this basalt through old river gravel and bedrock beneath it to a depth of 175 ft. below the pre-basaltic bed of the creek. Marginal streams have exposed the basalt of the tributary and the gravel and bedrock underlying it and have cut through the lava that was in Deep Creek, leaving residuals north and south of the tributary the tops of which are 700 ft. above sea level. This gives some idea of the length of time between the pouring out of the lava on the western side and the Tulloch Hill eruption and also the time from this eruption to the present day.

Other valleys to the north and east which drained between Mount Ridley and Crowes Hill and then turned south to the west of Merri Creek were filled with lava from Tulloch Hill. The present bank of Merri Creek from Summer Hill is also composed of rock from this lava.

Fairbank vent is perched on the side of a valley which followed the margin of the Crowes Hill lava flows in a westerly direction. Aitkens Hill erupted on the crest of a hill near the junction of Silurian bedrock and granodiorite. It filled valleys on its east and west flanks which had been eroded since the Crowes Hill eruption.

A basalt plain extends to the south from the 600 ft. contour south-west of Summer Hill and north of Woodstock. It rises from about 550 ft. above sea level on its western side to between 550 and 700 ft. on its eastern side and is about 7 miles in width. Merri Creek flows in a course between lava flows of different ages on the western side, its valley being from 20 to 30 ft. deep and gorge-like in character. Lime Creek which rises north-east of Summer Hill flows between lavas from Hayes Hill and Mount Frazer. Darebin Creek drains the eastern side of the plain.

Description of Vents

Green Hill

Green Hill, 1,250 ft., is a point of eruption 28 miles from Melbourne on the east side of the Hume Highway. It is probably the oldest of those described. The hill of accumulation was raised on the side of what was a hill of Silurian bedrock and across the valley of a small stream that now turns east, causing a deep deposit of alluvium to form, upon part of which the town of Wallan is built. The bedrock on the north and west sides of the hill is 1,050 ft. above sea level. On the south and east there are lava flows that are partly covered by Mount Frazer and Springs Hill, the part remaining being covered by alluvium caused by the blockage of Merri Creek by lava from Mount Frazer. This alluvium is thin on its western edge near the Hume Highway but increases in depth towards the east. At a point on the creek about 27 chains east of the Hume Highway there is a bed of mingled alluvium and volcanic lapilli, which by its elevation shows that the former water level was 3 ft. higher than at present. Near the railway bridge over Merri Creek the alluvium overlies a black volcanic soil, and has a clay-pan appearance. Half a mile east of Green Hill there is a ridge of fine sandy silt raised 3 ft. above the general level that probably

represents the level before Merri Creek had cut its channel to its present depth through the Mount Frazer basalts.

Green Hill is an almost round dome rather less than half a mile in diameter, the sides of which have a slope of 10°. Brown soil fills what was probably a small crater. It is built of small basalt flows and scoria beds on the north side and flows of alkaline iddingsite basalt on the south. Olivine basalt flows issued from the south-east corner where the sides of the dome are collapsed. On the east side there is more red scoria and spatter, although towards the top are short alkaline iddingsite basalt flows. There are erosion channels on this side. The west side is composed almost wholly of flows of iddingsite limburgite which has been extensively quarried. In some places it has a peculiar globular structure and breaks into two small pieces. Its top is scoriaceous. In a small quarry on the south-west end there is a bed of black vitric cinder four feet thick underlying a lava flow. The tachylite in it has decomposed to a dull black and most has devitrified to give a yellow-brown rock. This type of bed is unusual in this district though common in western Victoria. Stearns and Macdonald[2] consider material of this kind to have been deposited by lava fountains before the lava flows.

Mount Ridley

Mount Ridley, 16½ miles from Melbourne, is situated on the west side of the Hume Highway. It has two vents, the southern and older one being 950 ft. above sea level, the northern one lying about 30 chains on a bearing of N15°E connected by a saddle and being 50 ft. lower. Both are flat domes with a slope of 5° and the base of the hill of accumulation is about one mile north and south and three-quarters of a mile east and west, decreasing around the smaller vent. There are no crater depressions but it is possible to fix the points of eruption by the spatter and by changes in the surrounding rocks. The east sides of both vents rest on the side of a hill of bedrock at the 800 ft. contour.

The southern dome is composed almost wholly of flows, its south side being olivine basalt flows and scoria beds upon which lie ejected blocks and frothy basalt. The flows, which have issued mainly from the south-west corner, have covered the countryside up to Summer Hill to a depth of 132 ft. but are overlain near Patterson's Creek by lava from Tulloch Hill. The soil on them is loamy, 10 ft. deep in places, and before ploughing was covered with buckshot gravel. There is also black soil of fair depth on the dome. The west side displays olivine basalt on the base as far as Patterson's Creek, and short thick flows of similar rocks to the summit. A bore on the summit went through 100 ft. of scoriaceous rock and then into 200 ft. of solid basalt before it was discontinued, so is probably on the vent. The east side is a viscid non-vesicular flow of olivine basalt which crosses the Hume Highway, where it is 10 ft. thick, and terminates about 200 ft. east of the road. The north side is olivine basalt as far as the saddle between the two vents and has a base built of flows of this rock from 39 to 80 ft. thick, which poured down a hillside of bedrock to the north and north-west as far as Kal Kallo Creek, where they are overlain by lava from other vents. To the north-east they reached Merri Creek and filled the gap between hills of bedrock. The creek has since cut a gorge in which is disclosed the structure of a lava flow. The top is a vesicular basalt which appears to have solidified rapidly. There is a chilled border touching the sides and bottom of the infilled valley inside which is a zone of decomposed earthy lava with small round boulders of coarse-grained non-vesicular lava in it. The earthy lava grades into a slightly vesicular pahoehoe lava, which obviously has flowed through the other. The author concludes that the earthy type was formed by accretion of semi-crystalline

lava from the pahoehoe. It was probably moving until it set and the small boulders are probably centres of crystallization.

The smaller northern dome seems to be much younger because its basalt issued in well-defined streams over the older lava. The steep top is dense limburgite, 75 ft. thick, the uppermost few feet being finely vesicular and slaggy. It consists of small phenocrysts of iddingsitized olivine in a groundmass of augite, sometimes with patches of analcite, and is well exposed in the upper quarries on the hillside. The lower quarries are in olivine basalt in which the olivine is partly iddingsitized and the groundmass is largely titanaugite, plagioclase being the minor constituent.

A bore into bedrock at a point 300 ft. east and 100 ft. north of the north-east corner of the Hume Highway and Seventeen Mile Lane disclosed a dyke at a depth of 90 ft. The dyke is thought to be much older than the volcanic rocks being described. The rock consists of zoned plagioclase the core of which is acid labradorite, laths of a normal brown hornblende with a relatively high extinction angle, and abundant groups of almost colourless amphibole aggregate which is almost certainly pseudomorphous after pyroxene. Grains of magnetite are scattered throughout and a small amount of quartz is present. The rock is mineralogically and texturally quite unlike the basalts.

Crowes Hill

Crowes Hill, 17 miles from Melbourne, is half a mile west of the junction of Fifteen Mile Lane and Old Sydney Road, Yuroke. There are two points of eruption but neither has a crater. The hill of accumulation of the main vent is an almost flat-topped dome with a slope of 5° to the sides. It is 1,000 ft. above sea level and originally had a base half a mile in diameter. On its south-east side the base rests on Silurian sandstone at an altitude of 800 ft. which is exposed in a small dam on the west side of Old Sydney Road. The northern and eastern sides of the hill consist of consolidated scoria. Immense flows of olivine basalt have issued from the base of the south and west sides and overlying these are short rough flows of alkaline olivine basalt which show abrupt ends on the west side. The summit on the east side is covered with spatter and cellular pumice and a deep well near the centre penetrates pahoehoe normal and alkaline olivine basalts. The final flow of olivine basalt from the summit poured down the north-east corner and covered the country with pahoehoe lava to the north and east.

The smaller vent lies N39°W of the main vent and is 950 ft. above sea level. It has piled up a cone on the side of the main dome, the combined base of the vents being a mile long and half a mile wide. It is a lava plug surrounded by spatter and short flows of alkaline olivine basalt, there being a large amount of lithic scoria on the north side of the vent.

These vents are among the oldest, and deep valleys have been eroded in the lava flows which poured south down ancient valleys on both sides of the granodiorite into Broadmeadows, Glenroy, Pascoe Vale, Brunswick and Carlton districts. The soil is deep and covered with buckshot gravel. The lava on the north and east sides of both vents is partly covered with that from Tulloch Hill.

Bald Hill

Bald Hill is a prominent landmark about 1½ miles east of the Hume Highway between Kal Kallo and Beveridge. The point of eruption is not as large as the size of the hill suggests as it is on a hill of Silurian bedrock 1,000 ft. above sea level, which on the east has a slope of 20°. To the west it slopes at about 5°, extending across the Hume Highway. The point of eruption is about 30 chains in diameter

and is composed mainly of red consolidated scoria which rests on basaltic lava that has flowed into valleys on its east and south-west sides. A stiff, non-vesicular flow of alkaline limburgitic olivine basalt issued on its western side. This is exposed in a quarry near the Highway and is more than 120 ft. thick at a well three-quarters of a mile from it. The rock consists of completely iddingsitized olivine phenocrysts, augite phenocrysts and groundmass, poikilitically enclosed in relatively large anhedral optical units of a felspar showing occasional imperfectly developed albite twinning and possessing variable refractive indices between the limits of 1·550 and 1·536. This is probably a high temperature oligoclase in which potash may be present. Although the chemical composition of the rock would be that of an alkaline olivine basalt it has the character of a limburgite with a great excess of alkali felspar. The top of the point of eruption consists of short flows of analcite limburgite.

The summit of Bald Hill, 1,176 ft. above sea level, has a small crater almost filled with brown soil. A bore on the 900 ft. contour 100 yds. north of the outcrop of bedrock on the east side of the hill penetrated bedrock under 35 ft. of scoria. Vesicular, black basaltic lava poured down the north-east corner of the hill to the north and east, most of it later being covered by Mount Frazer lava. Information from some bores on this side of the hill is worth recording. On Congram's Road, which runs south from Donovan's Lane, and about 100 yds. from the Lane, a bore disclosed 14 ft. of basalt and below it bedrock soil containing much quartz. Another at the end of Congram's Road on the 900 ft. contour passed through scoria and ash, finishing in bedrock at 90 ft. One on Tolmie's property just west of the house on the 850 ft. contour is 82 ft. deep, passing through scoria into bedrock.

Basaltic lava issued from the south-west corner and covers the country south and south-west as far as Bunker Hill. It is very vesicular in places. Some has visible phenocrysts of augite. Bores in the western valley show that it is about 110 ft. thick. Its surface is flat near the vent but develops crescentic ridges broadside on to the flow, which in one case becomes a broad flow standing about 20 ft. above the others. It finishes at Bunker Hill as a flow about 220 yds. wide with a pear-shaped end standing 25 ft. above the surrounding country. Its top is made up of rounded boulders and at Bunker Hill it shows disturbance in the shape of upturned blocks. Boulders are scattered on other parts of the lava field and the ends of flows are conspicuous. The low-lying parts are covered with soil and are waterlogged in winter.

Fairbank Vent

Fairbank Vent, 750 ft. above sea level, is due south of Crowes Hill and due west of Aitken's Hill. It is not described as a hill because the points of eruption, of which there are two, are now the edge of a plateau. The remains of one are visible as an eruption of brown olivine basalt, with a spatter and cellular scoria slope on the east side, on which there are a few pieces of ejected granodiorite. From the base there have been flows of iddingsitized olivine andesine basalts. The other is 100 ft. south, covered by a house. Part of a rough spatter cone can be seen which seems to have extruded a viscid iddingsitized olivine alkaline basalt over the western flanks and part of the northern flank of the first cone, making an almost flat plain that is almost level with the top of the cones. This rock weathers to give the appearance of brain coral and on broken surfaces looks as though made up of small globules. The flows on the plateau were probably of the aa type as the soil is full of small stones which have decomposed into a deep loamy light-coloured soil.

Granodiorite outcrops about 20 chains south of the vents and confines the lava from them. About 30 chains south-east of the vents a shallow well disclosed granodiorite under the lava.

Aitken's Hill

Aitken's Hill is about 2 miles south-east of Yuroke. It is 874 ft. above sea level and its base is about 30 chains in diameter. The vent is on a ridge and near the junction of Silurian bedrock and granodiorite, which it has covered with a hill of accumulation. The granodiorite is 700 ft. above sea level just south of the vent, the base of which is lower than the granodiorite. The cone is composite and built up of scoria on the east side, of lava flows and scoria on the north and south sides, and of lava on the west. The summit is a blunt V-shaped and dyke-like plug, one leg of the V pointing to Fairbank vent and the other to Crowes Hill. The outer edge forms a wall with serrated top, up to 6 ft. in width and 8 ft. in height. The inside of the V is lava, which is a somewhat alkaline iddingsitized olivine basalt, and the blunt point seems to be the point of extrusion of a flow of mauve lava which extends down the west side for about 20 chains. On the north-west side, 160 yds. from this point, there is another dyke-like plug from which lava has flowed to the north and north-west until it reached Aitken's Creek.

The earliest flows seem to have been of basalt, some of which has visible phenocrysts of augite. The flows filled a valley on the west, where a bore showed a depth of 120 ft. to granodiorite, and south-east of the bedrock and granodiorite ridge, in this case the flow coming from the west side around the south of the vent. The lava was evidently not very fluid as there are no tumuli on it and it is covered by a fair depth of soil containing small stones. It stands above the plain and was probably aa or scoriaceous. It extends to Broadmeadows, where the ends of the flows are conspicuous, and narrow flows follow valleys into Coburg.

The lava fields are shown as No. 6A on the map but their age in relation to the others could not be fixed. They are later than those of Crowes Hill and probably about contemporaneous with or somewhat earlier than those of Hayes Hill (No. 6).

A basaltic spatter and scoria cone formed about the vent during the basalt flows and its outer layers seem to have oxidized to a bright red and consolidated before the alkaline basalt plug was intruded through it because some of the beds on the south side show fractured and upturned edges. Nearby are thin flows of vesicular lava which appear to have flowed down the cone at about the same time. The plug seems to have been extruded in a semi-solid condition, the top 8 or 9 ft. being finely vesicular but the lower part non-vesicular. It seems as if a considerable part was extruded as many blocks lie about the cone on the outer side. There was evidently a liquid portion of the plug inside the V as a few pieces of granodiorite and large quantities of cellular lava, bombs, including breadcrust bombs, blocks of brown lava with ropy top still preserved, and a large amount of bright red scoria, probably part of the basaltic cone, were ejected. Under the straight portion of the cone is a bulbous portion which seems to have distended the cone and forced the straight portion up.

On the west side, about 50 chains from Aitken's Hill, there is now a deep narrow valley, and half a mile on the south-east side is a shallower flat-bottomed valley. Both have been eroded in basalt by the headwaters of the Moonee Ponds Creek which is older and more mature than Merri Creek.

Tulloch Hill

Tulloch Hill, 950 ft. above sea level, is about a quarter of a mile west of the junction of Seventeen Mile Lane and Old Sydney Road, Mickleham. Tulloch Hill, Crowes Hill and Fairbank Vent lie on an almost north-south line. There is little ejected material and the lava slopes away from the vent on all sides. The summit has a slope of 5° and is made up of short flows, some of the rock of which is salmon

coloured. The final flow is olivine basalt with visible phenocrysts of augite. The lava does not appear to have been very fluid as there are no tumuli upon it. The hill of accumulation rests on Silurian sandstone. A bore about 146 yds. east of the vent and another 50 yds. north of it disclosed a thickness of 173 ft. of lava. About 30 chains farther north the thickness is 65 ft., all three bores being on the 900 ft. contour. This vent was active after Mount Ridley and Crowes Hill as its lava overlies that from these vents. Patterson's Creek flows along the junction of Mount Ridley and Tulloch Hill lava. On the east side of Deep Creek valley Crowes Hill lava is almost entirely covered and normal iddingsitized olivine basalt from Tulloch Hill is exposed as the ends of infilled valleys.

Hayes Hill

Hayes Hill is not quite 2 miles east of Donnybrook railway station. It has a pear-shaped base about 30 chains north to south and about 20 chains east to west. It is 900 ft. above sea level at its highest point, the north end, which seems to be above the point of eruption. There is no crater, the north, east and west sides being composed to red vesicular scoria capped with spatter and ejected blocks. The north side has a slope of 15°. On the south side, on which there seems to be no scoria, lava flows extend from the top of the cone, falling at a steady slope of about 6° near the hill to form the plains.

The top flow, an alkaline limburgitic basalt, flowed south for about 30 chains. A bore about 20 chains south-east of the vent disclosed loose scoria under a thin cap of basalt. Another, about 50 chains west, penetrated 175 ft. of basalt before it was discontinued, probably having another 10 ft. of basalt beneath it. A bore on the south-east side on the 775 ft. contour penetrated 160 ft. of basalt, indicating a level of 590 ft. for the bedrock, giving a height of 330 ft. for the cone above bedrock.

It is impossible to say if lava from Bald Hill is buried under Hayes Hill but the author thinks it may be represented by a depression between Hayes Hill and Mount Frazer lavas. The lava from Hayes Hill filled the country to the east and south and occupies the valleys of the Plenty River and Darebin Creek. It reached the present site of Melbourne and from comparison with recent flows on the island of Hawaii it would have been flowing for about eight months. It still shows some of the more prominent features of the flows. Near the vent it is fairly level for about half a mile where a rather rough area of vesicular lava standing up 10 ft. occurs, apparently caused by a break in the conduit. About half a mile farther south the country has transverse concentric ridges.

The author considers that nearly all this basaltic lava was extruded at one time. The extent of the field is not extraordinary. Excluding the Plenty River basalt it is roughly 3½ miles broad but widens to about 6 miles near South Morang where it is joined by the tongue from the Plenty River valley. It contracts to less than 3 miles near Keon Park from where it extends down narrow valleys for 11 miles to the Melbourne district. The lava seems to have been pushed forward as a series of broad flows, which can be traced on the surface and slope away from the vent to the east, west and south. The surface is covered with pressure ridges and tumuli, most of them in a south-easterly direction which corresponds with the deepest bores. The surface within the mapped area has a fair amount of soil on it but the ridges are covered with medium-sized boulders, most of which are very vesicular. There is nothing to indicate what type of surfaces the flows had but from their general nature it was probably pahoehoe (ropy).

Mount Frazer

Mount Frazer, also known as Mount Bland or Beveridge Hill, is at Beveridge on the Hume Highway, 24 miles from Melbourne. Its appearance suggests its being a breached scoria cone with an angle of 15° on the north side and 10° on the east and west. On the south it descends in steps from the 1,100 to the 950 ft. contour. It rests on the eastern edge of the old middle interfluve, bedrock outcropping at 1,050 ft. above sea level on its north-western margin, giving 350 ft. as the height of its highest point above bedrock. The base on which it rests is about 1½ miles in diameter, rising on an easy grade from about 950 ft. to 1,150 ft.

It consists of a hill at the north-west end 1,350 ft. above sea level, about 15 chains wide and 20 long to the middle of the saddle which connects it to the next peak to the south-east, which is 1,400 ft. above sea level, 20 chains wide and 40 long. From this peak a narrow ridge, 1,200 ft. above sea level, extends S30°W for about 20 chains, then changes to the north-west for about 20 chains, ending in a peak 1,220 ft. above sea level.

On the west side Mount Frazer has a breach 150 yds. wide in front of which is a slope of about 15°. The breach broadens into a crater-like passage with a depression in the centre. There is a bank about 15 ft. high and then what appears to be a circular crater with a flat muddy bottom, 220 yds. in diameter and at an elevation of 1,150 ft. The sides have the angle of rest of scoria.

The scoria is unstratified and consists of vitric ash, lapilli, cinders, ejected bombs up to a foot in size, and a few blocks of finely vesicular basalt, all of it being "fire fountain" material as described by Stearns and Macdonald[2]. The fine material is unconsolidated and partly decomposed, under a consolidated coating of deep red scoria. The bombs contain inclusions of sedimentary rock, quartz, or olivine in all sizes up to about an inch. Sedimentary rock and olivine are also mixed with the scoria. Similar scoria occurs on the north side but on the east and south bombs predominate and there is much spatter on the peaks.

The author does not consider that the mountain is a breached cone or that the apparent crater, of which much of the roundness and flatness is caused by water action, is a true crater. It is thought that the sides are overlapping scoria cones of which the 1,400 ft. cone is the oldest. This overlies another cone or has had a landslide into the crater. The 1,350 ft. cone overlies it on the west side and whatever craters there may have been are just below the peaks on the north side. The 1,200 ft. ridge is a cone from which lava issued. The 1,220 ft. cone on the south side of the breach has a spatter top and overlies the ridge cone. The bank across the entrance to the false crater is a lava flow from this cone and there is also a small flow which issued from about 20 ft. up its side and flowed into the crater. The rock from this is a partly iddingsitized olivine basalt.

From the flanks of the various cones the points at which various lava flows issued can be seen and there may be some lava in the crater from flows. In front of the break where scoria would be expected there is none and what lava there is issued from under the scoria cones on each side. Ther may, in fact, be Silurian bedrock in front of the breach.

There are six small scoria cones, marked A to F in the map, at various places outside the above large ones. Some of them can be aligned with other points of eruption in the area, suggesting that they are located on lines of weakness in the bedrock. Cone A occurs 330 yds. west of the Hume Highway at the end of the north side of the breach. It consists of vesicular scoria and there appears to have been a lava flow from it, the cone being partly covered on the east with lava. It

lines up with the two southernmost of the large cones and Cone B, a much fresher-looking cone south-east of them, behind a house that is 330 yds. north of the junction of Station Road and Spring Street. Cone C, lying near the bottom of the bedrock slope on the south-east corner of Hume Highway and Station Road, is relatively large, and there issued from it a lava flow, the rock of which contains visible augite phenocrysts. Road cuttings on its north and east flanks expose unstratified scoria and bombs. It roughly lines up with the two western of the large cones and Green Hill. Cone D lies about 30 chains east and 10 north from this corner. Between D and C there is a flow from the southern flank of the main group of cones, which issued at about the same level as the flows inside the crater, and which extended to Lithgow Street. Cone E is at the north-west corner of Arrowsmith and Spring Streets. It is almost obliterated by lava. Along the east side of the cone from Station Road to Lithgow Street is an area of deep light soil suggesting the presence of Silurian bedrock but as there are no outcrops it has not been mapped as such. Cone F is half a mile north of Station Road in line with Spring Street. It differs from the others in that it has large blocks of extremely fine-grained glassy olivine basalt scattered about, having the appearance of a dyke rock. A bore located midway between Cones F and B went through 5 ft. of clay, 28 ft. of rough scoria, 28 ft. of lapilli and ash, 43 ft. of rough scoria, and 37 ft. of basalt. Cones E, B and F are in alignment.

To test the idea that Mount Frazer is not a breached cone the author carried out some experiments to find the figure which would result by pouring mounds to scale in the order worked out from field observations on to a ground plan of the vents. Sugar was used to secure the angle of rest and the result was a close copy of Mount Frazer.

The flows from Mount Frazer were mostly thick and sluggish, with slightly undulating surfaces with little debris on them. Their ends are visible on the plains and here and there are tumuli, the largest of which is Hill 60, 1¼ miles south-east of Beveridge railway station. Viewed from Woodstock it is prominent but it is merely a pressure dome on the end of a flow and rising 20 ft. above it.

The final big flow spread three-quarters of the way across the eastern valley and has an abrupt side standing 15 to 20 ft. above the underlying flows. Opposite Bald Hill it piled up on lava from Hayes Hill and probably also from Bald Hill. Where it encountered the underlying lava it developed crescent-shaped ridges facing broadside on to the flow and there is often a pressure ridge on the terminal points. The lava went around the west side of Hayes Hill where it has numerous crescentic ridges some of which develop into tumuli. It has short extensions from the sides, not shown on the map, and a prominent mound just south-west of Hayes Hill is just behind the end of such an extension and due to liquid pressure. It continued as a flow about a mile wide with an abrupt eastern edge and a high ridge on the western side, where the top is slightly undulating. It is virtually free of boulders except on some of the crescentic tumuli. It ends at the junction of Merri Creek and Lime Creek due east of the 12 mile post on the Hume Highway, as a tumbled heap of massive blocks with sides up to 6 ft. caused by the undermining by the streams. Here there is an exposure of a much older vesicular ropy basalt overlain by a pebble bed of bedrock detritus and lava which was later covered by the Mount Frazer lava.

Springs Hill

Springs Hill on the west side of the Hume Highway north of Mount Frazer was probably the last vent in the district to be active. Its highest point is 1,200 ft. above sea level. It is a basaltic cone with a roughly circular base one mile in diameter,

made up of numerous thick and thin flows of pahoehoe lava. The tops of the flows are rough and vesicular and extend to short distances from the vent, giving a terraced appearance on the west and north-west sides. Upon them may be seen loose blocks which enclose scoria and small boulders which are the equivalent of accretionary lava balls. There are also up-ended slabs that have been pushed along by other flows and show that some flows were only 12 to 18 inches thick. Upon the flows may be seen a few small gas blowholes. There is a small amount of lithic scoria around the vents but the whole hill gives the impression of quiet extrusion of cool lava that had lost most of its gases.

The bigger flows are up to 20 ft. thick and $1\frac{1}{4}$ miles in length and usually have a broad bull nose. They overlie Mount Frazer lava on the south and south-east and Green Hill lava on the north-east. They overlie Silurian bedrock and are overlain by alluvium on the north-west where they form a ridge which has blocked the drainage on the west side.

The top of the hill has a semi-circular ridge about 333 yds. in diameter around its north side which is made up of five small cones, its base being about 50 ft. thick. These cones have lip flows. The central cone is the highest, has a slope of 15° and is made up of lava flows and scoria with large blocks of vesicular lava on the peak. From the summit to the base there is a narrow thin flow of limburgitic andesine basalt. The lava from the other vents is olivine basalt rich in labradorite. The eastern cone stands on a base about 1,150 ft. above sea level and is about 15 ft. in height. The western end of the ridge is about 10 ft. lower than the central cone and is composed of large vesicular blocks. From it there issued a thick pahoehoe flow of vesicular lava which flowed south, the top of which is covered by boulders. The skin of pahoehoe is glassy and in recent flows the glassy skins of the tubes show as veins in the tops of the flows. In older flows such as those described these veins and skins weather first giving rise to boulders and wide irregular joints.

A flat semi-circular area on top of the hill covered with soil is shown on the map as partly Silurian bedrock because the soil contains much fine quartz silt. Bedrock mapped near the Hume Highway is identified on the same evidence.

Quartz Inclusions in Basalt

Inclusions of quartz occur in lava flows from many of the vents. A striking example occurs at Bunker's Hill in what appears to be the end of a basalt flow from Bald Hill which crosses the Hume Highway $18\frac{1}{2}$ miles from Melbourne. The inclusions of milky quartz are angular and of all sizes down from roughly cubic pieces seven inches across. With them are a few pieces of grey silicified sandstone and the common yellow fine-grained sandstone, some of which show signs of solution in the lava. When fractured the quartz has a lustreless porcellanous appearance. The pieces have innumerable cracks, some of which have basalt squeezed into them. The quartz shows signs of secondary silification and the basalt immediately surrounding it has rows of fine vesicles. The lava is moderately vesicular and many of the vesicles have secondary deposits around them. The inclusions seem to be almost confined to an upper and a lower limit.

The milky quartz seems to be derived from quartz veins within the Silurian bedrock and to have been ejected with the lava from the vent.

Mr. A. J. Gaskin sectioned some of this quartz and states "that the thin section showed that the material was still almost pure quartz, but the grain was so shattered that it was not possible to determine what the strucure migh have been, the shatter effect being caused by thermal expansion and contraction coupled with volume changes accompanying the 573°C. inversion. There are signs of isotropic material

in some of the shatter cracks together with minute wedge-shaped birefringent crystals. The transformation to tridymite or cristobalite begins at 870° and the rate is extremely slow up to 1000° unless mineralizers are present. With a short heating and no mineralizers the material could have reached 1,450° but the most likely lower limit of heating is 1,000°."

The author immersed fresh quartz from the district in cast iron at 1,400°C. Whether hot or cold it powdered and would only carry in a lava flow as very fine fragments. A 3 in. cube of quartz was then placed two-thirds the way down in a 2 ft. x 2 ft. slag container and slag at 1,400° poured around it. The cube took about six hours to cool and was difficult to recover, but the quartz looked much the same as that in the lava. The slag resembles and behaves much the same as basalt. This suggests that quartz picked up by the lava at 1,100° or 1,200° C. would finish in the state in which it is found in the cooled rock.

Similar inclusions of quartz occur in a cutting near "Warlaby" on Konagaderra Road, together with sandstone; on Fifteen Mile Lane between Craigieburn and Woodstock; in a cutting on the Woodstock Road three-quarters of a mile north of Woodstock and on the Donnybrook-Woodstock Road one mile east of the railway station; in a quarry on the north-west of Springs Hill and, as small pieces, in the bombs from Mount Frazer. It has been recorded from other places in Victoria by Fenner,[3] Grayson and Mahony,[4] Skeats and James[5] and Coulson[6].

Conclusions

The field evidence indicates a succession of eruptions and outpourings of lava from the Lower Pliocene or earlier to the Upper Pleistocene. Pretty Sally Hill and a vent north of Kilmore compare in degree of erosion and decomposition of their lava with the Greensborough Older Basalt. Springs Hill, where the steep central cone is mainly stony scoria with large blocks on the top and a dribble of limburgitic basalt down one side, is hardly touched by erosion and is probably Upper Pleistocene. Green Hill is an eroded rounded dome covered with a mantle of soil whose lava flows had a deep black soil on them before they were covered with alluvium. It was formed later than Pretty Sally Hill as it fills a valley that was eroded on the margin of the latter. It appears to have been in much the same condition as to-day by the time Mount Frazer erupted and caused its soil and lava flows to be covered with alluvium. By comparison with Springs Hill it is probably Upper Pliocene. Mount Frazer has a light mantle of red-brown soil and on the flatter part the tuff has decomposed to a fine yellow clay with a loamy soil on it. Mount Frazer lava is overlain by Springs Hill lava on its north-west corner and overlies Hayes Hill lava on the Donnybrook-Woodstock road. Hayes Hill is probably Lower Pleistocene as the point of eruption has suffered some erosion and is covered with a fair amount of black soil. Its lava flows are covered with deep soil in parts and it is covered with a good growth of trees. Bald Hill is overlain by lava from Mount Frazer. It is covered with a deep mantle of black or red soil. It seems to have erupted after a dormant interval and to have poured basaltic lava on its south-west side before flows issued from the north vent of Mount Ridley and Mount Frazer. The general erosion of the dome is much greater than that of Hayes Hill. It was probably active from Upper Pliocene to Lower Pleistocene. The south vent of Mount Ridley is thought to be Upper Pliocene as it is overlain by other flows but does not overlie any. Its flows are covered by a deep buff-coloured loamy soil containing buckshot gravel. This soil and the flows look similar to flows in Western Victoria that are considered to be Pliocene. Crowes Hill is considered to be about the same age as Mount Ridley but there is no definite evidence bearing on their relative ages. The

flows from Crowes Hill have a deep soil of light colour containing buckshot gravel and are much eroded on the Deep Creek side. Tulloch Hill is younger than Mount Ridley and Crowes Hill, as shown by exposures on Patterson's Creek, but its lava is overlain by that from Mount Frazer and its age is thought to be about the same as that of Hayes Hill. Aitken's Hill and Fairbank Vent are thought to be older than Mount Frazer, mainly on the evidence of the depth of soil on the respective lavas.

The points of eruption could be said to resemble the Phlegrean Fields in Southern Italy as they are from $1\frac{1}{2}$ to $3\frac{1}{2}$ miles apart and some look as if they were active only once or twice. Others are double vents. It is possible to line up certain vents such as:

(1) Hayes Hill, Vent F of Mount Frazer, Pretty Sally Hill and a vent three miles beyond it in a direction N10°W;
(2) Green Hill, Mount Frazer, Bald Hill;
(3) Green Hill, Springs Hill, Vent A of Mount Frazer and the two vents of Mount Ridley;
(4) Tulloch Hill, the south vent of Mount Ridley and a dyke three-quarters of a mile to the east lie in an almost east-west line which to the west coincides with a westerly-trending section of Deep Creek and to the east passes through a basalt-filled gap between Woody Hill and Summer Hill and also through the Mernda Gap;
(5) the two vents of Crowes Hill and Aitken's Hill;
(6) Fairbank Vent, Crowes Hill and Tulloch Hill.

It is notable that the big vents, Mount Frazer, Crowes Hill and Mount Ridley, are at intersections of lines.

The lava of the extensive flows which filled the valleys is olivine basalt. Olivine is visible in some flows north of Mount Ridley and certain flows south-west of Mount Ridley contain visible phenocrysts of augite. The vents themselves can be divided into two provinces, those that were active at a very early period and whose end-product was alkali basalt, and those whose end-product was limburgitic basalt or limburgite. The alkali basalts are all grouped on or near the granodiorite, though Tulloch Hill produced only olivine basalt with visible phenocrysts of augite. The limburgites are on and north of Mount Ridley and have been extruded after big flows of olivine basalt, usually on one side of the basaltic vent. It is likely that both the alkali basalts and limburgitic lavas are derivatives of olivine basalt, the alkali basalts being the products of a residual fluid that has been driven out of the almost fully crystallized magma by gas in the manner suggested by Shand,[7] the limburgite being the result of crystal settling.

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